Springer Tracts in Advanced Robotics

Volume 18

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Multi-point Interaction with Real and Virtual Objects

With 142 Figures and 10 Tables

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Foreword

At the dawn of the new millennium, robotics is undergoing a major transformation in scope and dimension. From a largely dominant industrial focus, robotics is rapidly expanding into the challenges of unstructured environments. Interacting with, assisting, serving, and exploring with humans, the emerging robots will increasingly touch people and their lives.

The goal of the new series of Springer Tracts in Advanced Robotics (STAR) is to bring, in a timely fashion, the latest advances and developments in robotics on the basis of their significance and quality. It is our hope that the wider dissemination of research developments will stimulate more exchanges and collaborations among the research community and contribute to further advancement of this rapidly growing field.

The edited volume by Federico Barbagli, Domenico Prattichizzo and J. Kenneth Salisbury is the outcome of a well-attended workshop which took place during the 2004 IEEE International Conference on Robotics and Automation.

The authors of the sixteen chapters are recognised as leading scholars internationally. A number of challenging problems on the forefront of today's research on physical interaction with real and virtual objects are covered, with special emphasis on modelling contacts between objects, grasp planning algorithms, haptic perception, and advanced design of hands, devices and interfaces.

Besides the theoretical advancement, most contributions survey the state-of-the-art in the field, report a number of practical applications to real systems, and discuss possible future developments.

As the first focused STAR volume in the popular area of haptics, this title constitutes a very fine addition to the series!

Naples, Italy
March 2005

Bruno Siciliano
STAR Editor

Preface

The goal of this book is to report on some of the most interesting research results that have been developed in recent years by the robotic manipulation and the haptics communities in their studies of physical interaction between hands (real, virtual, or remote) and objects.

The problem of robotic and virtual interaction with physical objects has been the subject of research for many years in both the robotic manipulation and haptics communities. Both communities have focused much attention on human touch-based perception and manipulation, modelling contact between real or virtual hands and objects, mechanism design, and stability of contact. However, as a whole, these problems have not yet been addressed from a unified perspective.

Researchers from the robotic manipulation community have usually dealt with multiple points of contact. Citing Bicchi's excellent survey on robotics hands [28], "*Robot hands are systems comprised of two or more fingers that act on a manipulated object via contacts. The presence of contact phenomena in manipulation makes it peculiar among other robotic systems, and clearly contact models deeply affect the analysis of manipulation systems*".

Researchers from the haptics community possibly have a longer history of studying how humans use their hands to perceive and manipulate their surrounding reality. However, computer haptics [250], the branch of the science of haptics closer to traditional robotics, has mostly neglected the effects of interaction through multiple points of contact and can surely benefit from related results of multi-point contact interactions in robotic grasping and manipulation.

The chapters in this book are edited versions of papers that were selected for presentation at the Multi-point Interaction in Robotics and Virtual Environment Workshop, which took place on April 27th, 2004 in conjunction with the International Conference on Robotics and Automation. The workshop's goal was to bring together experts from various branches of the robotics, virtual-reality, and human studies communities to address the study of physical interaction between hands (real, virtual, or remote) and objects. A subset

of the nineteen presentations given at the workshop are presented in this volume in an extended and more thoroughly reviewed form.

The organization of the material in the book is as follows. The first group of chapters is concerned with modelling physical contacts between objects. Such models can then be used for planning grasps or for creating more realistic haptic rendering algorithms. Two contributions dealing with modelling multiple physical contacts for haptic rendering and virtual environment simulations are *Rapid Collision Dynamics for Multiple Contacts with Friction* by D. Kaufman and D. K. Pai, and *Dynamic Proxies and Haptic Constraints* by G. Niemeyer and Probal Mitra. Chapter *Modelling and Controlling the Compliance of a Robotic Hand with Soft Finger-pads* by L. Biagiotti, C. Melchiorri, P. Tiezzi and G. Vassura, addresses experimental investigation of normal and tangential stiffness of soft materials to develop compliant pads for robotic hands, while chapter *Does torque minimization yield a stable human grasp?* by G. BaudBovy, D. Prattichizzo and N. Brogi, addresses the analysis of human tripod grasp.

The second group of contributions deals with algorithms for planning more efficient grasps. Three contributions, *Efficient and Precise Grasp Planning for Real World Objects* by C. Borst, M. Fischer and G. Hirzinger, *Grasp synthesis from example: tuning the example to a task or object* by N. S. Pollard and A. Wolf, and *Toward sensorless acquisition of multiple contact points between planar parts* by K. Egan, S. Berard, and J. Trinkle, deal with a variety of techniques that can lead to planning for more efficient grasps. Chapter *Semi-Autonomous Human-Robot Interaction for People with Disability* by P. Rani, M. Sarkar, R. Brackin and N. Sarkar, presents a robotic application that allows disable users to interact with objects through dynamically planning trajectories given a set of high-level task commands.

The third group of contributions focuses on human and/or machine haptic perception. Knowledge of such perceptual aspects can be used to design better haptic devices of robotic hands, to better understand the human perceptual system, or to create more efficient control schemes for robotic manipulation. Three chapters, *Evaluation of Multipoint Contact Interfaces in Haptic Perception of Shapes* A. Frisoli, F. Barbagli, M. Bergamasco, S.L. Wu, E. Ruffaldi, and *Contact Location Trajectory on the Fingertip as a Sufficient Requisite for Illusory Perception of Haptic Shape and Effect of Multiple Contacts* by H. Dostmohamed and V. Hayward, and *Tactile Flow and Haptic Discrimination of Softness* by A. Bicchi, E. P. Scilingo, D. Dente, and N. Sgambelluri, focus on perception of virtual objects through haptic devices allowing simultaneous tactile of force feedback through multiple contact points. Chapter *On Observing Contact States in Over-constrained Manipulation* by T. Murphey deals with on-line perception of contact state in over-constrained manipulation, and how this can be used to automatically create more efficient grasps.

Finally, the fourth group of contributions focuses on the design of robotic hands allowing new ways to manipulate real objects, and haptic interfaces or tele-robotic systems that allow for more realistic interactions with virtual

or remotely located objects. Chapter *Haptic Interfaces: Collocation and Coherence Issues* by C. A. Avizzano, S. Marcheschi and M. Bergamasco focuses on designing haptic interfaces allowing interaction through multiple points of contact featuring collocated visual and haptic workspaces. Chapters *Effects of Gripping and Translational Forces on Teleoperation* by L. N. Verner, K. A. Jeung, and A. M. Okamura, and *Intrinsically Passive Control using Sampled Data System Passivity* by S. Stramigioli, deal with creating more cost effective and more stable tele-robotic systems. Finally, chapter *Design of 100G Capturing Robot* by M. Kaneko and M. Higashimori, focuses on designing of a highly responsive robotic hand system capable of capturing falling objects.

February, 2005

Federico Barbagli
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